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DESCRIPTORS- *ENVIRONMENTAL INFLUENCES, *ILLUMINATION LEVELS, *LIGHTING, *PERFORMANCE CRITERIA, *SCHOOL ENVIRONMENT, EVALUATION TECHNIQUES,

THIS PUBLICATION REGARDING SCHOOL LIGHTING WAS PREPARED AS A USEFUL ADDITION TO THE AMERICAN STANDARD GUIDE FOR SCHOOL LIGHTING. THE MATERIAL HAS BEEN EXTRACTED FROM THE IES LIGHTING HANDBOOK TO INCLUDE A MORE DETAILED TREATMENT OF SUBJECTS TO WHICH THE DESIGNER MUST GIVE IMPORTANT CONSIDERATION. THERE IS A MORE EXTENSIVE TREATMENT OF REFLECTED GLARE THAN APPEARS IN THE AMERICAN STANDARD GUIDE. THERE ARE PHOTOGRAPHIC EXAMPLES OF MODERN SCHOOL LIGHTING PRACTICE, A CONVENIENT LISTING OF THE SOCIETY'S CURRENTLY RECOMMENDED LEVELS OF ILLUMINATION FOR SCHOOL APPLICATIONS, AND A SEPARATE TREATMENT OF THE PROBLEMS INVOLVING DAYLIGHT AS A SOURCE. ALSO INCLUDED IN THE APPENDIX ARE SECTIONS ON THE EVALUATION OF THE EFFECT OF SPECULAR REFLECTION AND ELECTRIC LIGHTING SYSTEMS. THIS DOCUMENT IS ALSO AVAILABLE FROM THE ILLUMINATING ENGINEERING SOCIETY, 345 EAST 47 STREET, NEW YORK 17, NEW YORK, FOR $0.20. (RK)

SCHOOL LIGHTING APPLICATION DATA

Excerpts from the
IES Lighting Handbook
3rd Edition

Illuminating Engineering Society
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School Lighting Application Data

This publication has been prepared by the IES with the belief that many interested in school lighting will find it a useful addition to the "American Standard Guide for School Lighting." The material has been extracted from the* IES Lighting Handbook *(the text used extensively by designers of lighting systems) to include a more detailed treatment of subjects to which the designer must give important consideration. For instance, there is a more extensive treatment of reflected glare than appears in the American Standard Guide. There are photographic examples of modern school lighting practice, a convenient listing of the Society's currently recommended levels of illumination for school applications, and a separate treatment of the problems involving daylight as a source.

THE GOAL in school lighting is to produce a visual environment in which seeing may be accomplished efficiently and without hindrance or distraction from any part of the luminous elements of that environment. Adequate levels of illumination, with properly balanced brightnesses, help the educational process by making seeing quicker, surer and easier. Good lighting aids impaired vision, reduces visual fatigue and helps in the creation of a cheerful and pleasant atmosphere.

QUALITY

The quality aspect of lighting embraces all factors which contribute to visual comfort in the seeing process. It may be divided into two parts for convenience of discussion. One phase of lighting quality is that which a person experiences when working with his head down, as when a student is doing visual work at his desk. The other is that to which a person is subjected when his head is up and his line of sight is essentially horizontal, as when he is listening to, or observing, a lecture demonstration. While these are two distinctly different situations they are inter-related by the constant shifting of the student's visual attention and by the dynamic nature of the seeing process. The trend toward conference type teaching, where students may face any direction, indicates the need for visual comfort for all orientations in the classroom.

BRIGHTNESS RELATIONSHIPS

Research in visual performance indicates that the best seeing condition for viewing a specific task at any given level of illumination occurs when the brightness of the task, for example the page of a book, is just somewhat greater than the brightness of its background, which in this case would be the desk top.* The general approach in providing low brightness ratios over the entire visual field is to limit the brightness of the luminaires and fenestration (see Visual Comfort) and to build up the brightness of all other interior surfaces in the area (ceiling, walls, trim, floor, work surfaces and equipment) by suitable reflectances, textures and distribution of light.

ROOM AND EQUIPMENT REFLECTANCES

Good reflectance values of the principal surfaces of the room and its furnishings will help produce the desired brightness goals, assuming a generally uniform distribution of light over the surfaces of the room. These values are given in Fig. 1 and Table I. The single value shown for each element of the environment is a target value. Slight departure is permissible when practical or esthetic reasons so indicate. The range, shown in brackets, indicates the latitude of departure considered satisfactory from the single value.

Color—Color in the classroom is very desirable from both an interest and an esthetic standpoint. A trend in school design is to use several colors,

*1 to ⅓ between task and adjacent surrounds and remote darker areas.
1 to 10 between task and remote lighter surfaces at 30 footcandles. The ratio should decrease as the level of illumination increases. (See "American Standard Guide for School Lighting.")

TABLE I—Recommended Surface Reflectances for Schools.

SURFACE	REFLECTANCE IN PER CENT
Ceiling	85 (70-90)
Walls	60 (50-70)
Floor	30 (20-50)
Chalkboard	15 (5-20)
Desk tops	40 (35-50)

each within the recommended range of reflectances, for the various classrooms of the school. The use of one color together with another harmonious color or a grey of the same reflectance for adjacent walls of a classroom can add interest to the room and still maintain a good brightness environment. Small areas of darker and more saturated colors than permitted by the recommended range, when used judiciously, lend interest to the visual environment and provide a change of pace. When used with good color harmony, such accents are considered permissible if the darker and more saturated color areas occupy only a small part of the visual field.

VISUAL COMFORT

The lighting in a classroom should be as visually unobtrusive as possible. When the light sources, electric or daylight, become too bright they become visually objectionable. Depending on the degree of brightness, glare sources become progressively distracting and uncomfortable until eventually they produce disability glare conditions where seeing is actually impaired.

Average luminaire brightness is considered the most significant factor in control of direct glare. Direct glare should not be a problem in 100-footcandle fluorescent lighting installations if: (1) the ceiling and wall reflectances comply with Fig. 1, and (2) the luminaires used have crosswise and endwise average brightness distributions which fall entirely below any straight line drawn through 250 footlamberts at 75 degrees lying between the two limiting curves of Fig. 2. Computations of average brightness should be made at 10-degree intervals from 45 to 85 degrees. The sloping line indicates that high angles are more significant in causing direct glare than low angles for a luminaire of nonuniform brightness. A luminaire which has its average brightness near the limits of the curves at high angles must have comparatively low average brightness at lower angles in order to comply. Conversely, if its brightness at the lower angles is near the limit, its design must be such that brightness is well-restricted at the higher angles. (See "Recommended Practice for Office Lighting" and "American Standard Guide for School Lighting.")*

REFLECTED GLARE**

Reflected glare is the glare effect caused by the brightness of the reflected image of a light source. There are two aspects of reflected glare. The first and more important is the change in contrast that may take place in the task detail under certain conditions. The second is the reflection of bright sources in glossy or partially glossy surfaces in areas immediately adjacent to the task.

Within the Task—Many visual tasks have surface characteristics that are partially glossy and because of this they have a relatively high reflection in

*Illuminating Engineering, June 1960 and April 1962, respectively.
**See also Appendix B.

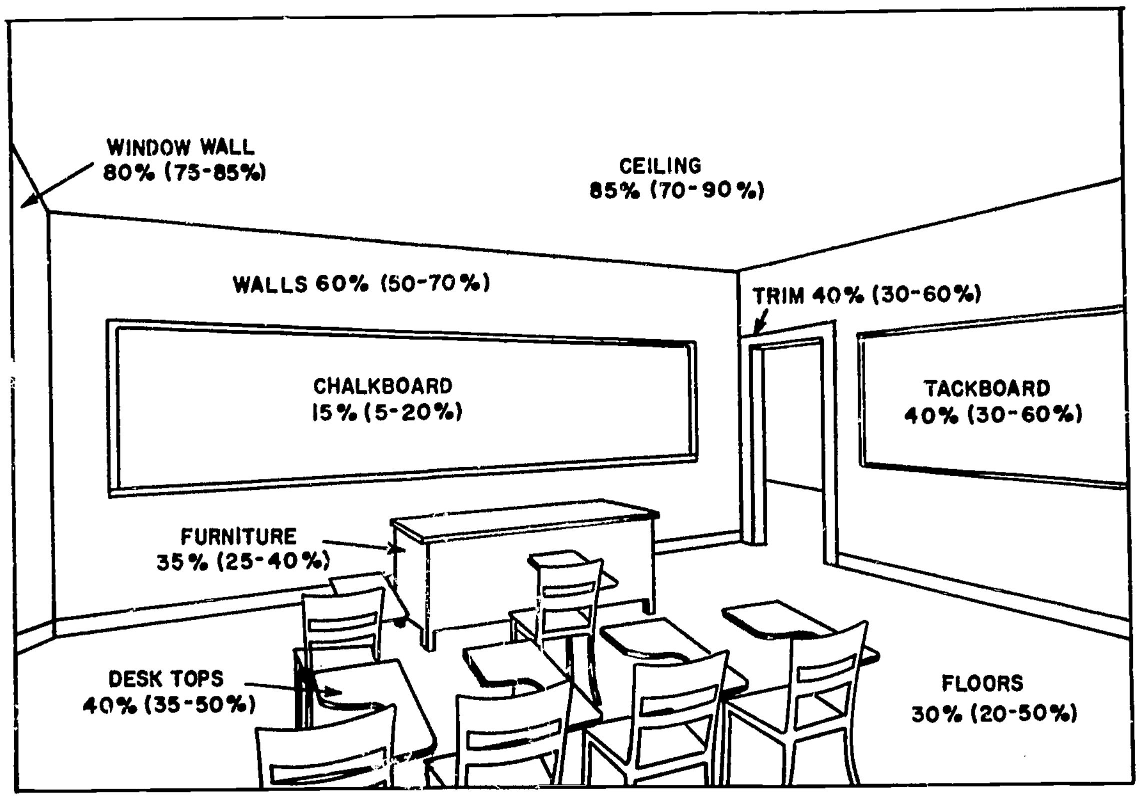
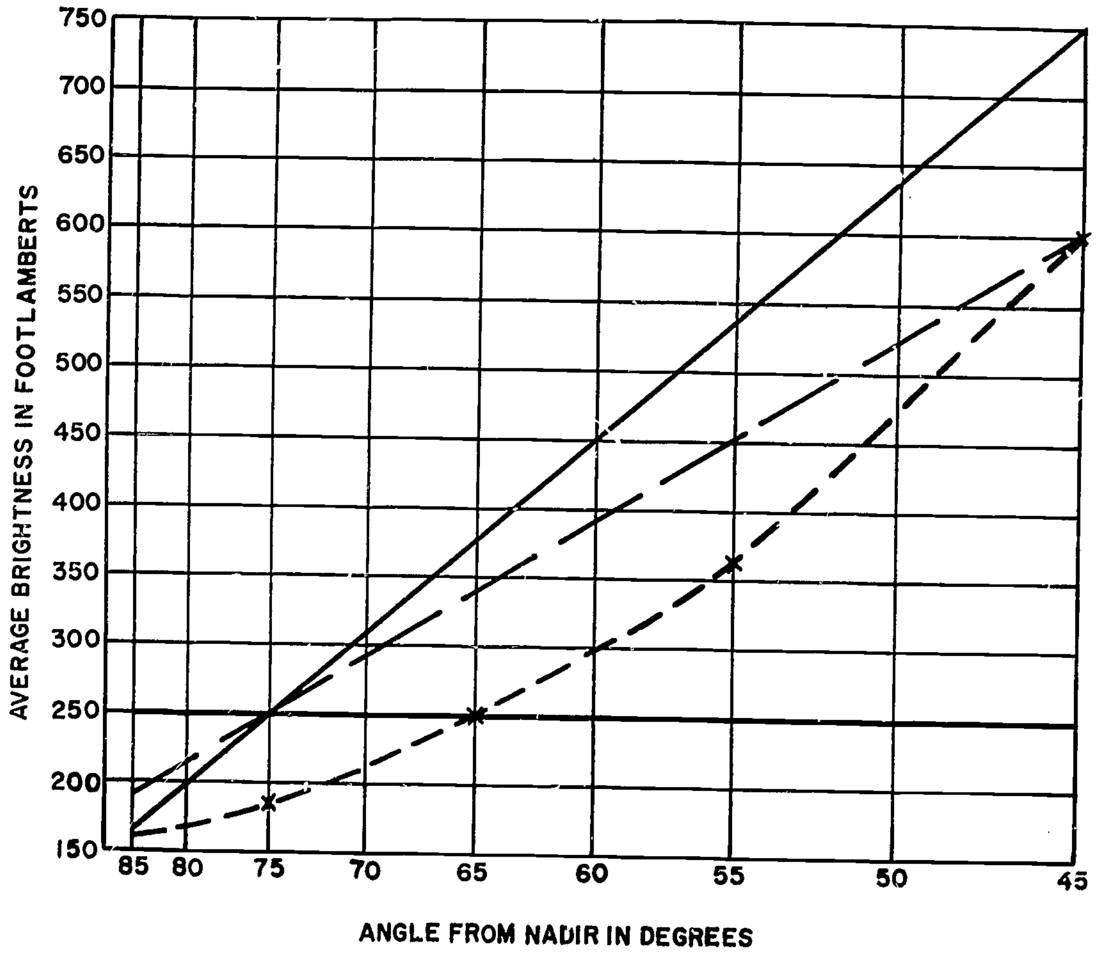


Figure 1. Recommended classroom reflectances.

Figure 2. Direct glare zone limiting brightnesses. Direct glare should not be a problem in 100 footcandle fluorescent lighting installations if ceiling and wall reflectances comply with Fig. 1 and if the luminaires used have crosswise and endwise average brightness distributions which fall entirely below any straight line(s) drawn through 250 footlamberts at 75 degrees lying between the two limiting solid lines.

The curve illustrated (short dashes) is the average crosswise brightness distribution for a specific luminaire. It complies with the brightness limits since all parts of the curve fall below the straight line (long dashes) lying between the two limiting lines and passing through 250 footlamberts at 75 degrees. The lengthwise average brightness should also be checked for compliance.



directions close to the mirror angle with respect to the incident light. One such task is pencil writing on matte white paper. The pencil strokes exhibit partial specular reflection with the result that if an appreciable amount of the light falling on the task is coming in the direction of mirror reflection with respect to the angle of view of the observer, the brightness of the pencil lines is increased to a much greater extent than the brightness of the matte paper background. The increased brightness of the pencil lines causes a reduction in contrast between the pencil and the background with a consequent reduction in visibility. High luminaire brightness in the 0- to 45-degree zone and high window brightnesses are common sources of glare that can reduce the contrast of visual tasks that are common in the schools.

For any given visual task the maximum loss in contrast, due to specularity, will occur when all of the light falling on the task is at the "mirror" angle with respect to the line of view. Because pencil lines are only partially specular, this loss in contrast takes place over a relatively wide angle. This probably accounts for the subtleness of the loss in contrast due to specular reflection. It is not usually apparent to the observer except in extreme cases. The minimum loss in contrast will usually occur when the light falls on the task in approximately the same direction as the observers' line of sight. Such a lighting method is not feasible for school classrooms where a large number of occupants are in the room and where pupil orientation is unrestricted. Loss in contrast from reflected glare can be minimized by limiting the brightness and area of light sources in the 0- to 45-degree zone (see Fig. 3), by adding illumination in favorable directions or by improvements in the characteristic of the task.

Outside the Task—Glossy furniture and room surfaces can produce reflected images of light sources and cause a condition of distraction or annoyance glare. A desk top with a glossy varnished surface, or a glass desk top, or a highly polished metal trim molding which can reflect a high brightness light source are common examples of this form of reflected glare. Equipment for classrooms should be as nonglossy as possible to avoid this condition.

QUANTITY

An evaluation of the newer data on visual performance indicates that the investigations by Blackwell provide information covering a wide range of task variables. Certain unique analyses suggest that his data may have relatively wide application to practical seeing situations. Blackwell has developed an interesting and unique method for relating his fundamental laboratory data for one specific target to typical practical visual tasks. He has included a consideration of the many differences between laboratory conditions and the conditions encountered in the normal use of the eyes. Recommended footcandle values are shown in Table II and Appendix A.

Uniformity of illumination is considered satisfactory if the minimum value is two-thirds or more of the maximum. This is necessary to insure a balance of brightness in the area and to permit flexible arrangement of operations. Many manufacturers publish maximum spacing-to-mounting height ratios for their luminaires which should be used as guides to proper installation.

For purposes of conducting maintenance surveys, using light meters in rooms of typical classroom size, the average footcandle level may be considered to occur at the center of one of the quarter sections of the room away from the windows. This simplification permits the custodian to determine easily when the illumination level has dropped below its designed minimum and corrective maintenance is necessary. The footcandle level from the electric lighting may be checked during the daytime when operating voltage conditions are typical. The combined footcandle level of the daylight and electric light should be measured first. The electric light is then turned off and the daylight measured alone. The difference is the illumination produced by the electric lighting system, assuming that the daylight has been relatively stable during the two readings. Light meters should be color- and cosine-corrected.

GENERAL CHARACTERISTICS OF SCHOOL LIGHTING SYSTEMS

The various types of daylight and electric lighting systems* used in schools each have their own specific characteristics, merits and limitations. These differences should be considered in deciding the specific lighting system suitable for each of the many different areas of a school. For example, at certain times the need for illumination in a kindergarten room may be more for a cheerful luminous environment than for critical seeing. On the other hand, in a drafting room the emphasis may be reversed, the principal need being illumination for critical seeing, with the cheerfulness of the environment important, but of secondary consideration.

For most school applications the standard cool white fluorescent lamp has been the most widely used choice. It has the general appearance of a white light source, renders colors reasonably well and blends well with daylight. The standard warm white lamp more nearly resembles the color of the incandescent filament lamp and is about four per cent more efficient than the cool white lamp. It may be used where a warm-toned atmosphere is desired and where a color blend with daylight is not considered essential.

*See Appendix C, Electric Lighting Systems, and Appendix D, Daylighting in Classrooms.

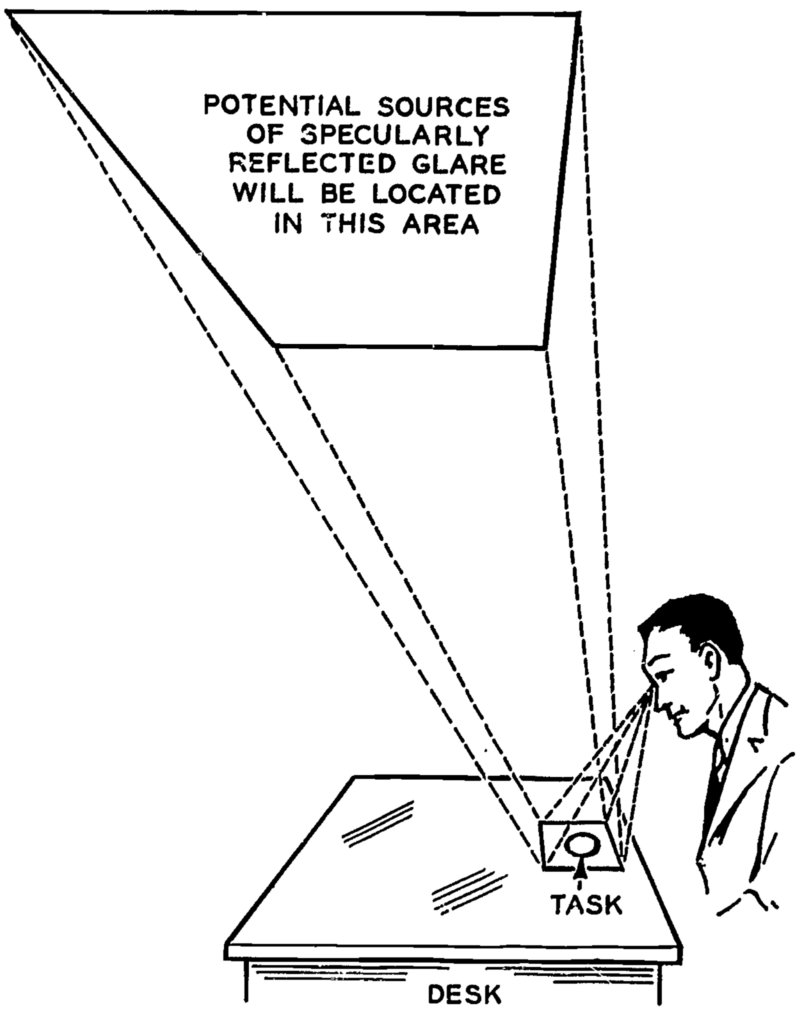


Figure 3. Method for determining zone in which potential glare sources may be located.

TABLE II—Levels of Illumination Currently Recommended for Classrooms.*

TASKS**	FOOTCANDLES ON TASKS***
Reading printed material	30
Reading pencil writing	70
Spirit duplicated material	
Good	30
Poor	100
Drafting, benchwork	100†
Lip reading, chalkboards, sewing	150†

*For a tabulation of specific applications see Appendix A.
**Tasks are listed here rather than areas, as previously published.
***Minimum on the task at any time.
†In some cases it is necessary to use local lighting to supplement the general illumination. These cases are generally found where it is economically unfeasible to produce the recommended footcandle levels from a general lighting system. Quite frequently seeing tasks are on oblique rather than horizontal surfaces. This results in a reduction in illumination and a consequent loss in task brightness. Also, some of the seeing tasks are more difficult because the contrast between the paper and the printing may be very low. In both of the foregoing cases, supplementary illumination is sometimes required or indicated. Care should be used in the choice of supplementary lighting units, so that they will not direct objectionable glare into the eyes of any worker. The distribution of the light across the working surface should be as uniform as possible.

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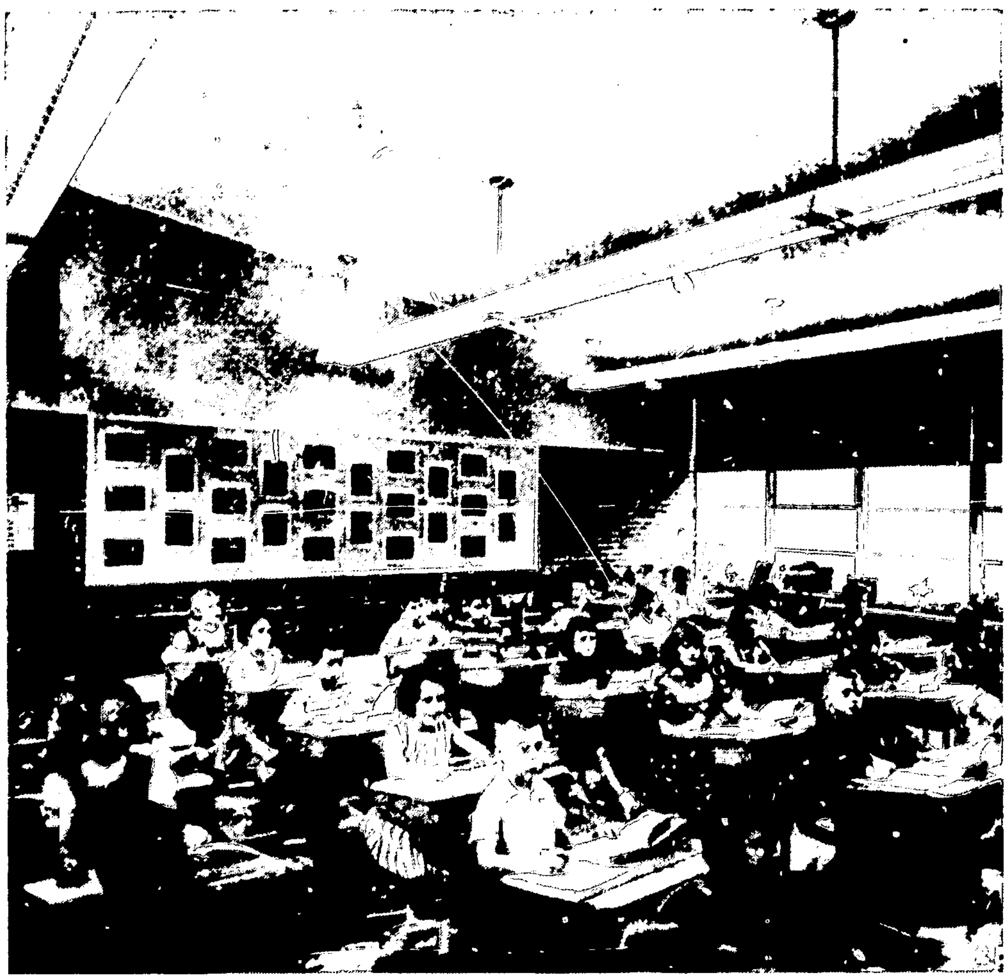
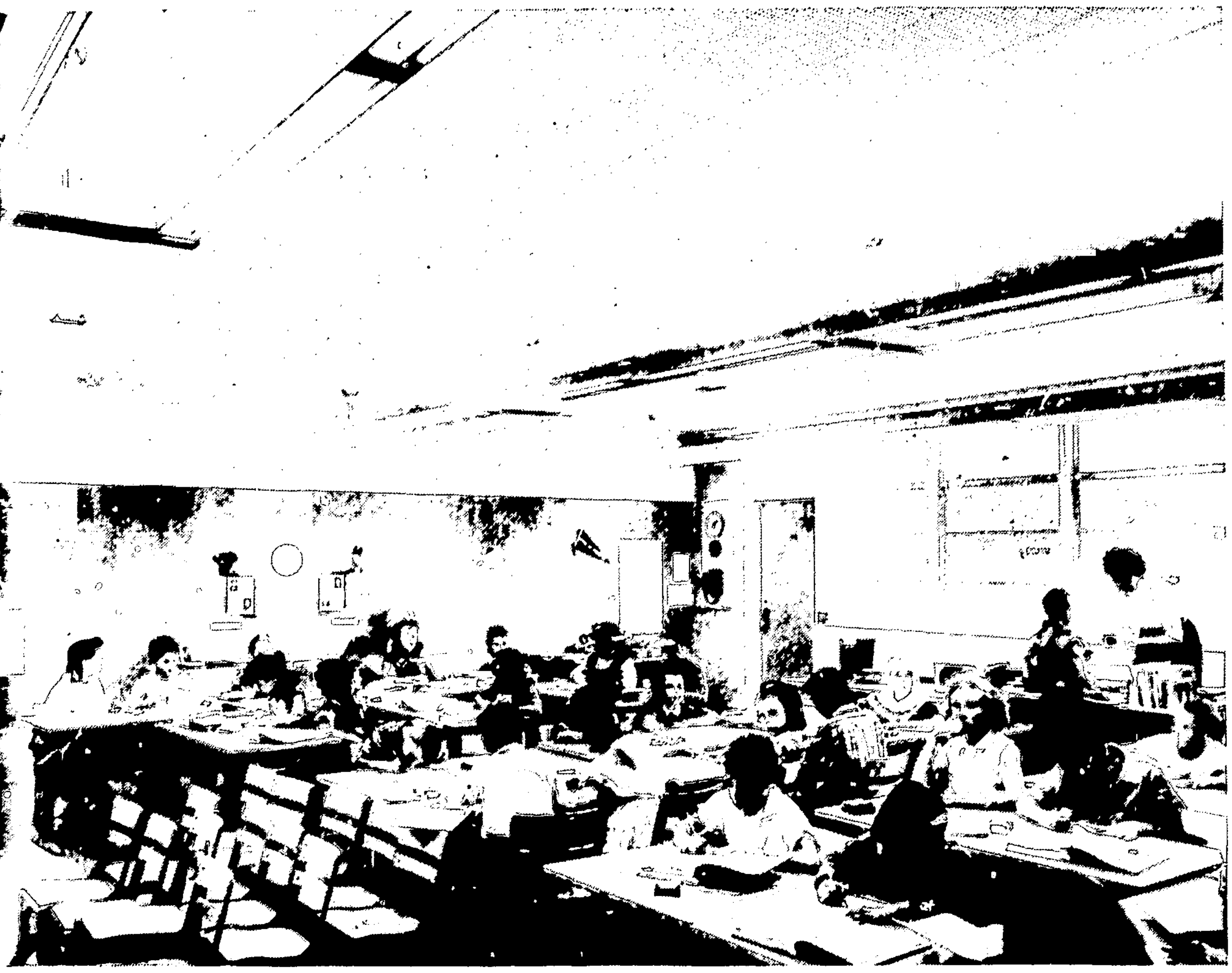
SAMPLE APPLICATIONS



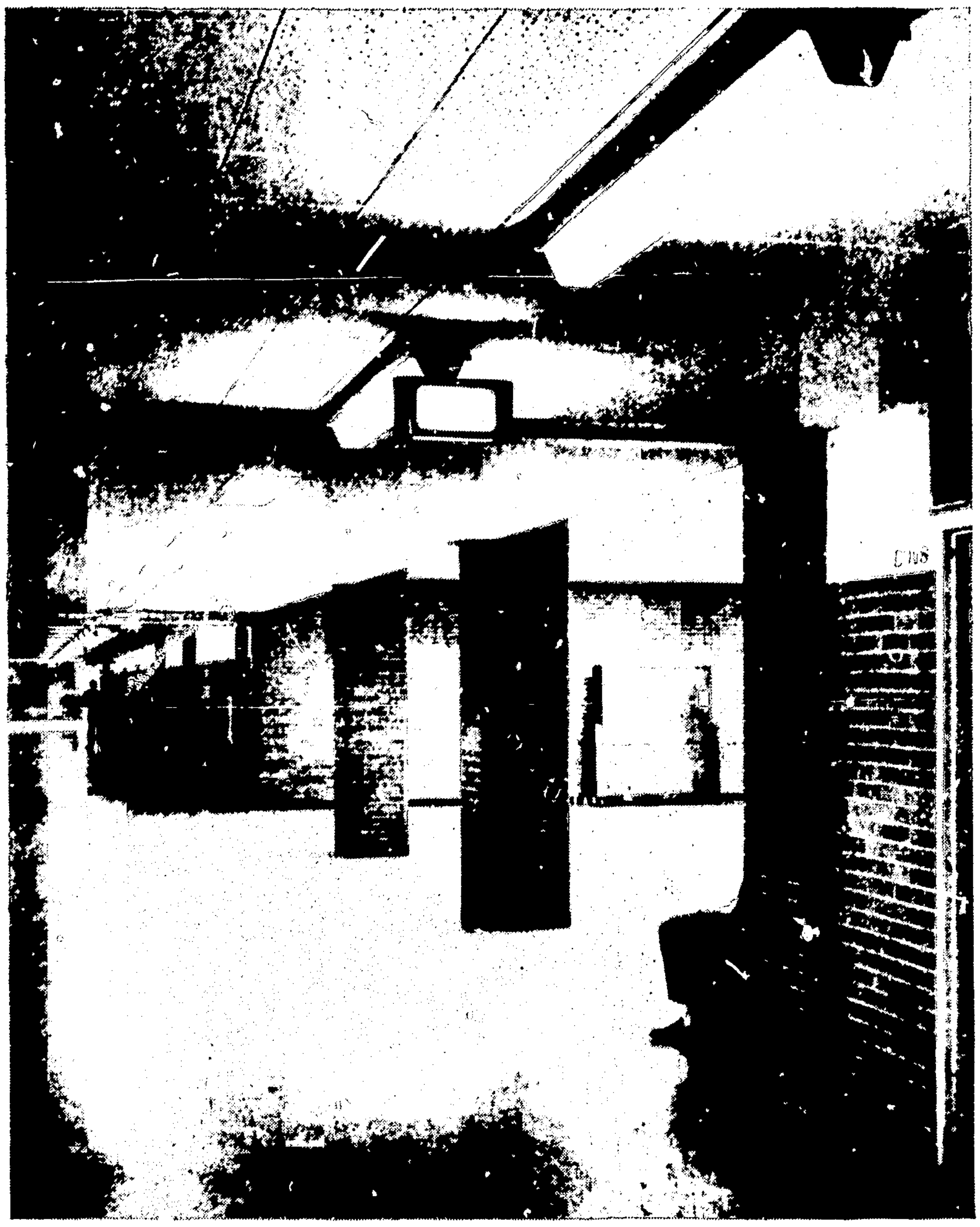
Daylighting should be subject to brightness limitations the same as electric lighting. Brightness, controlled by means of shades, is satisfactory when properly controlled by teacher. Bi-lateral daylighting by means of clerestory, left, helps balance the daylight illumination but is difficult to control in brightness. All luminaires are suspended at the same level despite the slanted ceiling, in order to maintain a feeling of balance in the room. Sixty footcandles is provided.

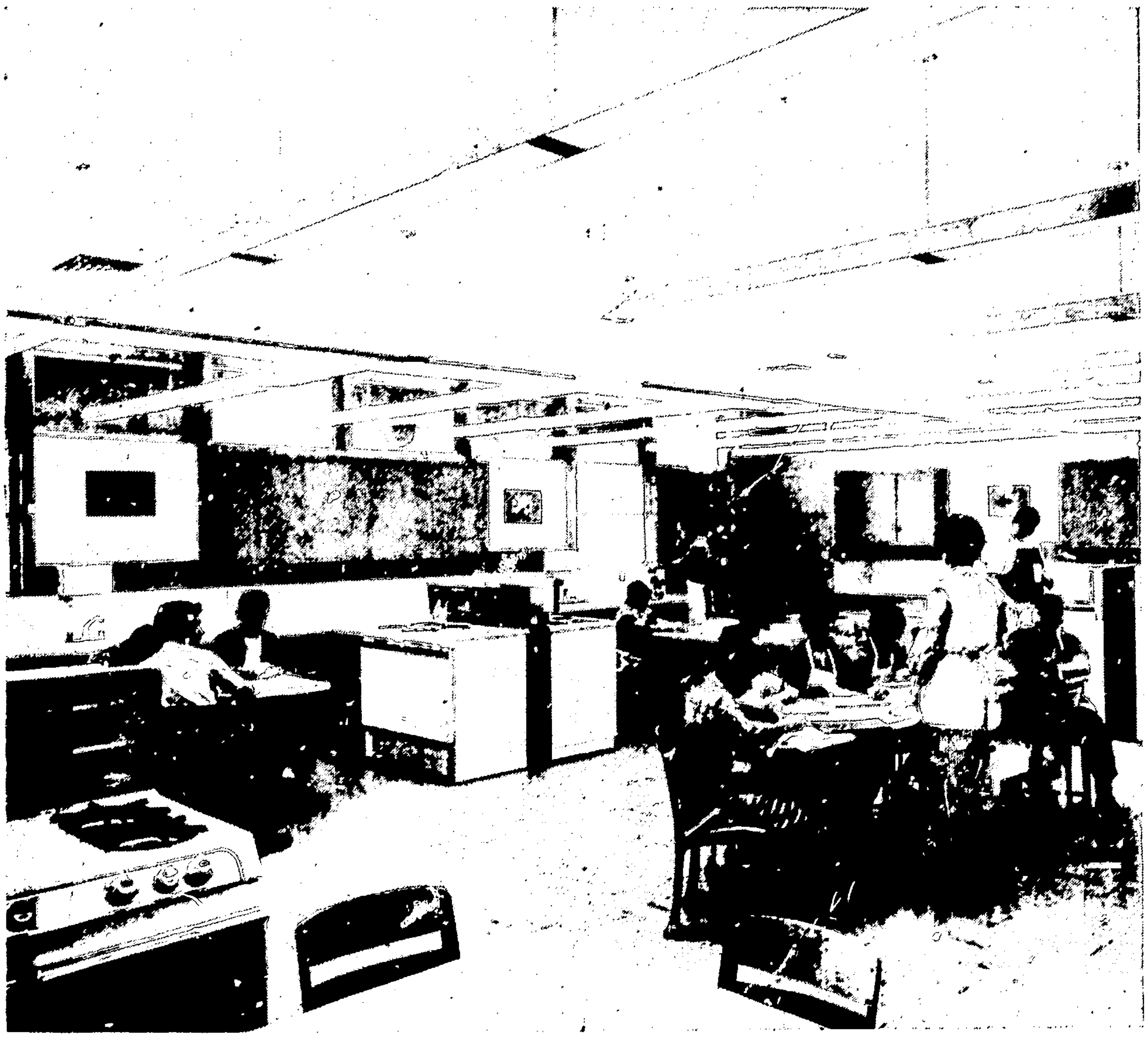
A close-up of one solution for chalkboard illumination. Seventy footcandles is provided.



An illumination level of 70 footcandles is provided in this elementary classroom. Luminaire design separates lamps and provides a somewhat smooth brightness distribution on the ceiling. Outside brightness is reduced with low transmission window glass (about 12 per cent) in three lower panels and high transmission glass in top panel that is shielded from sky by a wide canopy overhang.

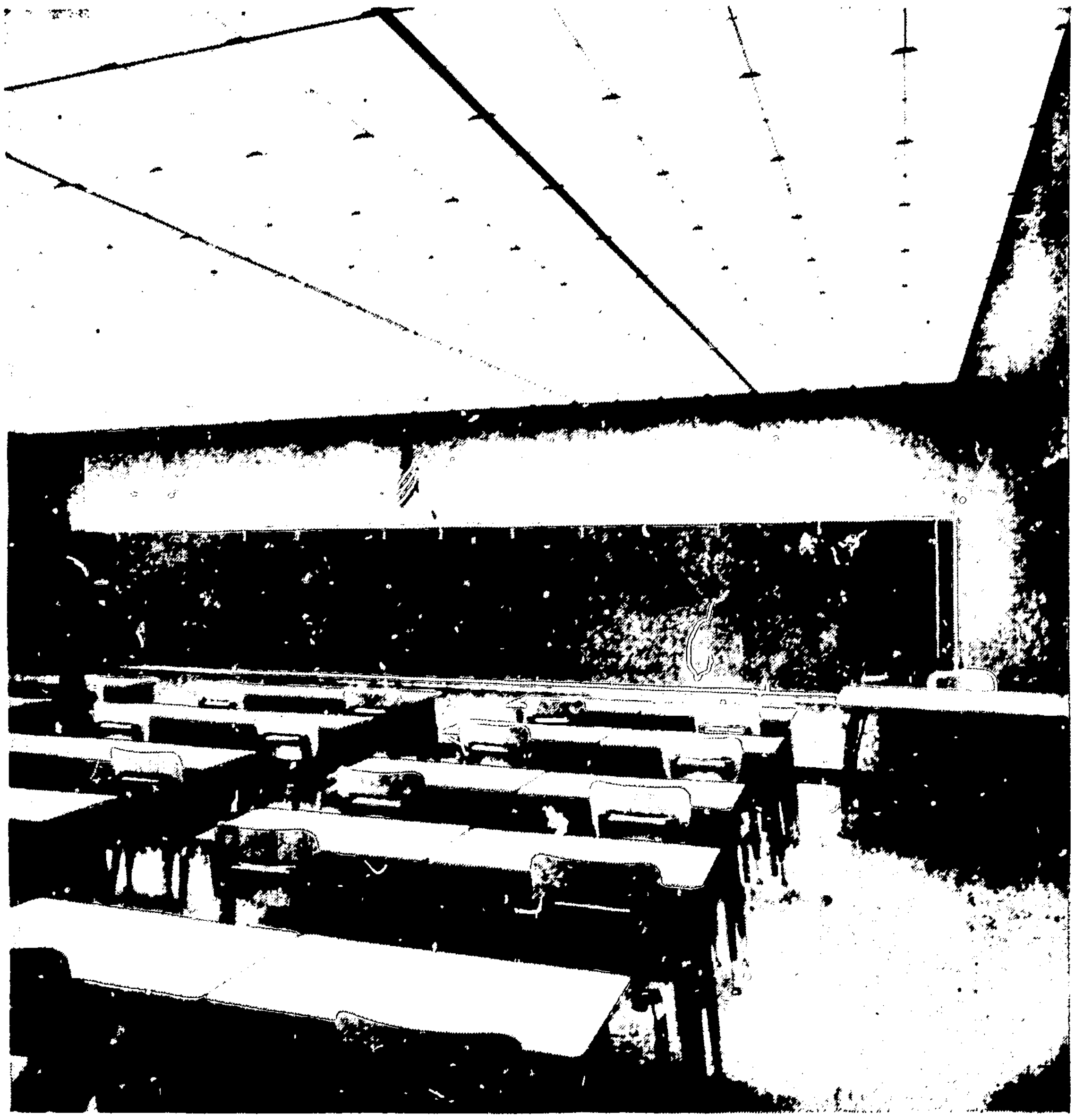
Surface-mounted luminaires in this corridor have a broad distribution of light to illuminate walls, faces and interiors of lockers. Recessed luminaires at entrance provide simpler appearance, lower brightness for all angles of view than surface-mounted units. Floor tile is practical for maintenance and contributes to cheerful atmosphere.





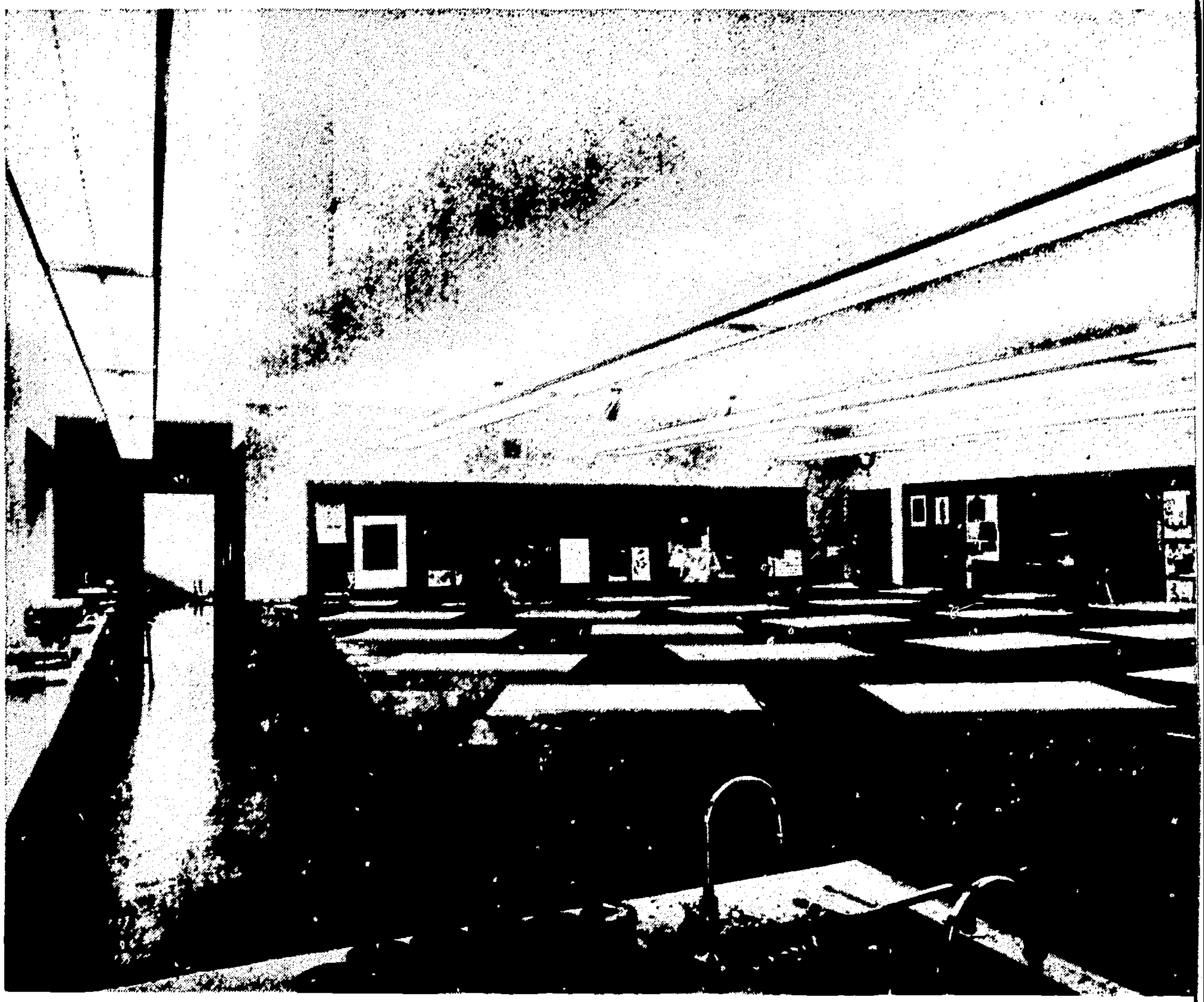
The luminaires in this home economics room provide an average level of 85 footcandles. Spacing of luminaire elements provides smooth brightness distribution on the ceiling. Window at sink is of low transmission glass (about 12 per cent) to reduce outside brightness to an acceptable level. Top panels of high transmission glass are shielded by wide, sloping canopy, so that only reflected ground light is utilized. Improved-color fluorescent lamps should be used for good color rendering.

An older school where the dark desk tops were refinished. Reflectances of new tops are satisfactory, but other surfaces such as floor, chalkboards, seats and sides of desks are undesirably low. Three rows of two-lamp luminaires provide uniform illumination of 70 footcandles.

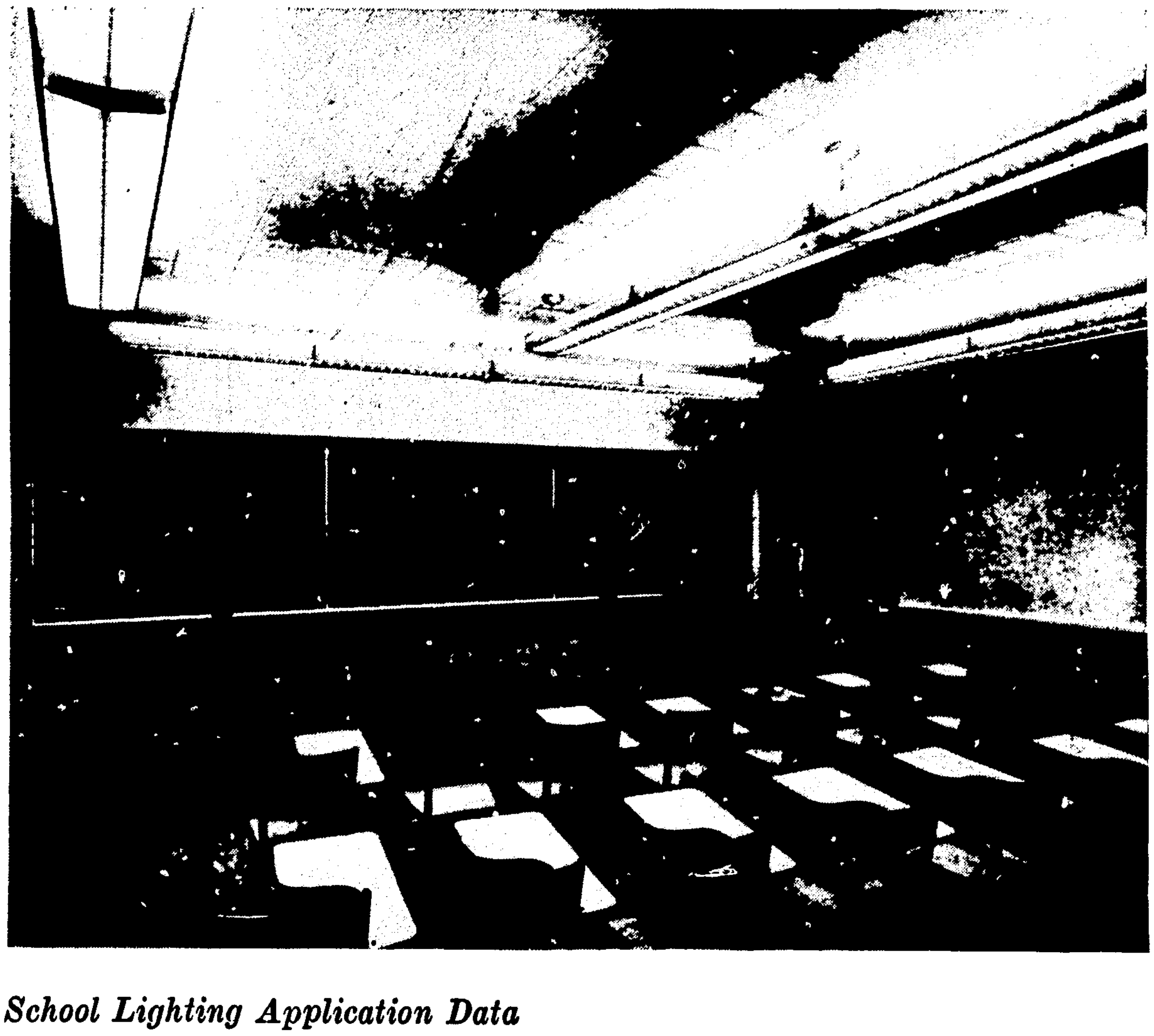


The luminous ceiling in this classroom provides 100 footcandles. The "modular" ceiling makes maintenance easier. Use of natural wood panelling for walls, relates appropriately to wood parts of chairs, and adds interest to the environment. Window wall (not shown) has opaque draperies on traverse to control brightness from outside.

The use of interesting materials such as brick and wood adds interest to the classroom. Where light colored materials are chosen, as was done here, comfortable, pleasant brightness relationship can be obtained. Note the quiet pattern of the floor. The pattern of lighting units is more pleasing here than if it had been run continuously in this odd-shaped space. Note control of window brightness by means of draperies. A level of 65 footcandles is provided.



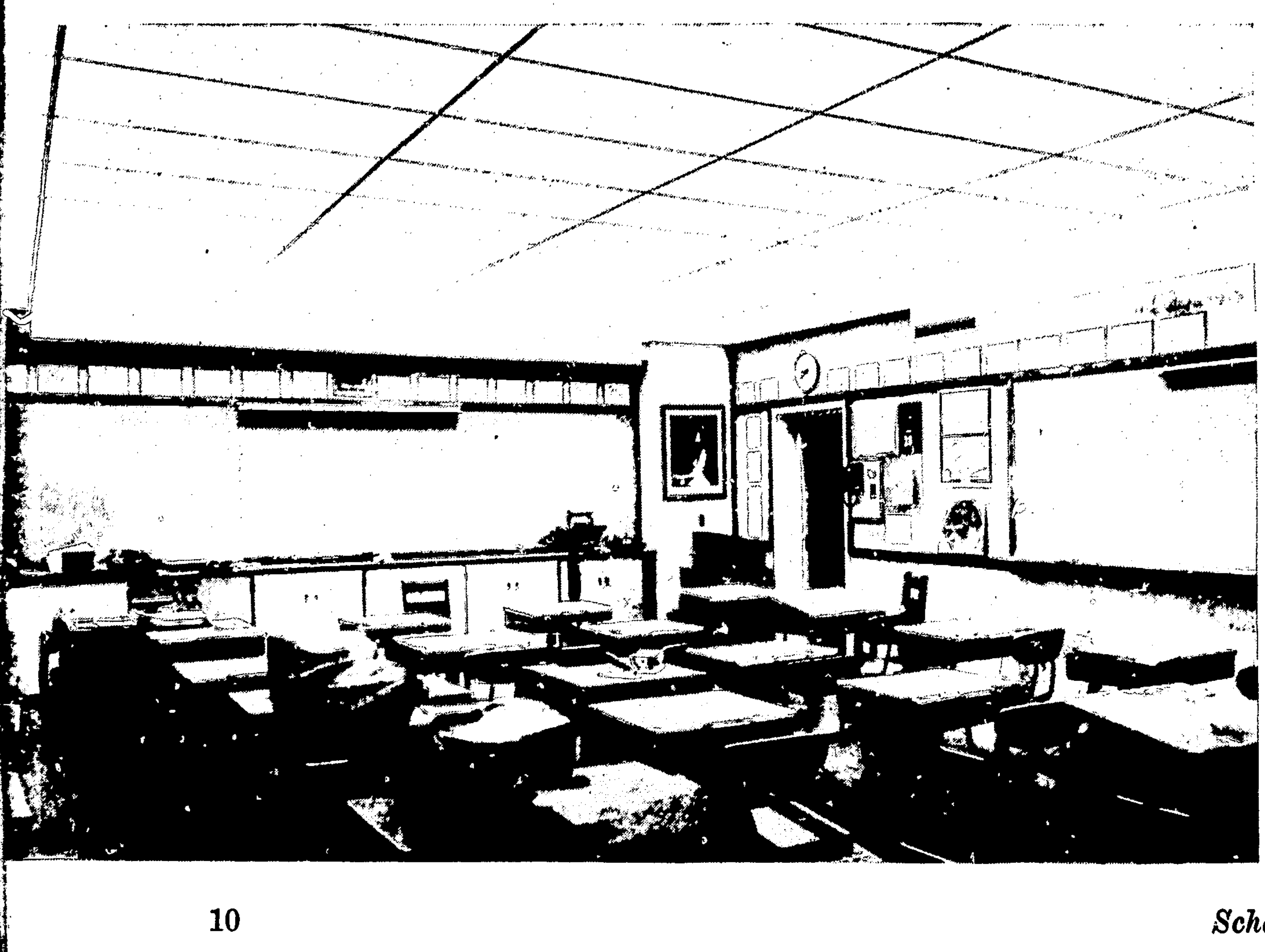
All-metal, well-shielded luminaires provide 70 footcandles in this art room. Ceiling-mounted, adjustable spotlamps at the front of the room provide "modeling" effect for art subjects and more illumination to help reveal details of the models for students at rear. Improved-color fluorescent lamps are used here to provide good color rendering.



The level of illumination in this classroom is 70 footcandles. The additional row of units parallel to the chalkboard increases the illumination on this important surface. However, specific chalkboard lighting is to be preferred. If luminaires were suspended lower than shown, there would be a more even distribution of light on the ceiling.

A chalkboard lighting installation in which the lighting unit is specifically designed for chalkboards and has a reflector to provide good uniformity from top to bottom of the board. General illumination is provided by a luminous ceiling with acoustical baffles. Use of high-output fluorescent lamps provides 150 fc.

The aluminum louverall ceiling installation in this sightsaving classroom provides an average level of approximately 180 fc on the desks. Note the almost complete absence of shadow from this lighting system. Supplementary lighting for increased illumination on the front and side chalkboards is from surface-mounted units equipped with high-output fluorescent lamps. ■



APPENDIX A—Levels of Illumination Currently Recommended for Specific School Areas. (Taken from Fig. 9-53, pages 9-76 through 9-86 of IES Lighting Handbook, Third Edition. Where exact area was not located, value determined from listed area with similar task.

AREA	FOOTCANDLES ON TASKS*
Auditoriums (See also Theatres)	
Assembly only	15
Exhibitions	30
Social Activities	5
Cafeterias	
Dining area†	30
Cashier	50
Food displays	70
Kitchen	
Inspection, checking, pricing	70
Other areas	30
Classrooms	
Art rooms	70
Drafting rooms	100**
Home economics rooms	
Sewing	150**
Cooking	50
Ironing	50
Sink activities	70
Notetaking areas	70
Laboratories	100
Lecture rooms	
Audience area	70
Demonstration area	150**
Music rooms	
Simple scores	30
Advanced scores	70‡
Shops	100**
Sight-saving rooms	150**
Study halls	70
Typing	70
Corridors and stairways	20
Dormitories	
General	10
Reading books, magazines, newspapers	30
Study desk	70
First aid rooms	
General	50
Examining table	100
Gymnasiums	
Exhibitions, matches	30
General exercising and recreation	20
Dances	5
Lockers and shower rooms	20
Badminton	
Tournament	30
Club	20
Recreational	10

AREA	FOOTCANDLES ON TASKS*
Basketball	
College and professional	50
College intramural and high school with spectators	30
College intramural and high school without spectators	20
Volleyball	
Tournament	20
Recreational	10
Library	
Reading room	
Study and notes	70
Ordinary reading	30
Stacks	30
Book repair and binding	50
Cataloging	70
Card files	70
Check-in and check-out desks	70
Lounges	
General	10
Reading books, magazines, newspapers	30
Offices	
Accounting, auditing, tabulating bookkeeping, business machine operation and reading poor reproduction	150
Regular office work, reading good reproductions, reading or transcribing handwriting in hard pencil or on poor paper, active filing, index references, mail sorting	100
Reading or transcribing handwriting in ink or medium pencil on good quality paper, intermittent filing	70
Reading high contrast or well-printed material, tasks and areas not involving critical or prolonged seeing such as conferring, interviewing and inactive files	30
Parking areas	1
Storerooms	
Inactive	5
Active	
Rough bulky	10
Medium	20
Fine	50
Swimming pools	
General and overhead	10
Underwater	#
Theaters	
During intermission	5
During motion picture	0.1
Toilets and washrooms	30

*Minimum on the task at any time.

**In some cases it is necessary to use local lighting to supplement the general illumination. These cases are generally found where it is economically unfeasible to produce the recommended footcandle levels from a general lighting system. Quite frequently seeing tasks are on oblique rather than horizontal surfaces. This results in a reduction in illumination and a consequent loss in task brightness. Also, some of the seeing tasks are more difficult because the contrast between the paper and the printing may be very low. In both of the foregoing cases, supplementary illumination is sometimes required or indicated. Care should be used in the choice of supplementary lighting units, so that they will not direct objectionable glare into the eyes of any student. The distribution of the light across the working surface should be as uniform as is possible. (Page 11-21, IES Lighting Handbook.)

†If used also as a study hall a level of 70 footcandles is recommended.

‡When score is substandard size and notations are printed on the lines a level of 150 footcandles or more is needed.

#100 lamp lumens per square foot of pool surface.

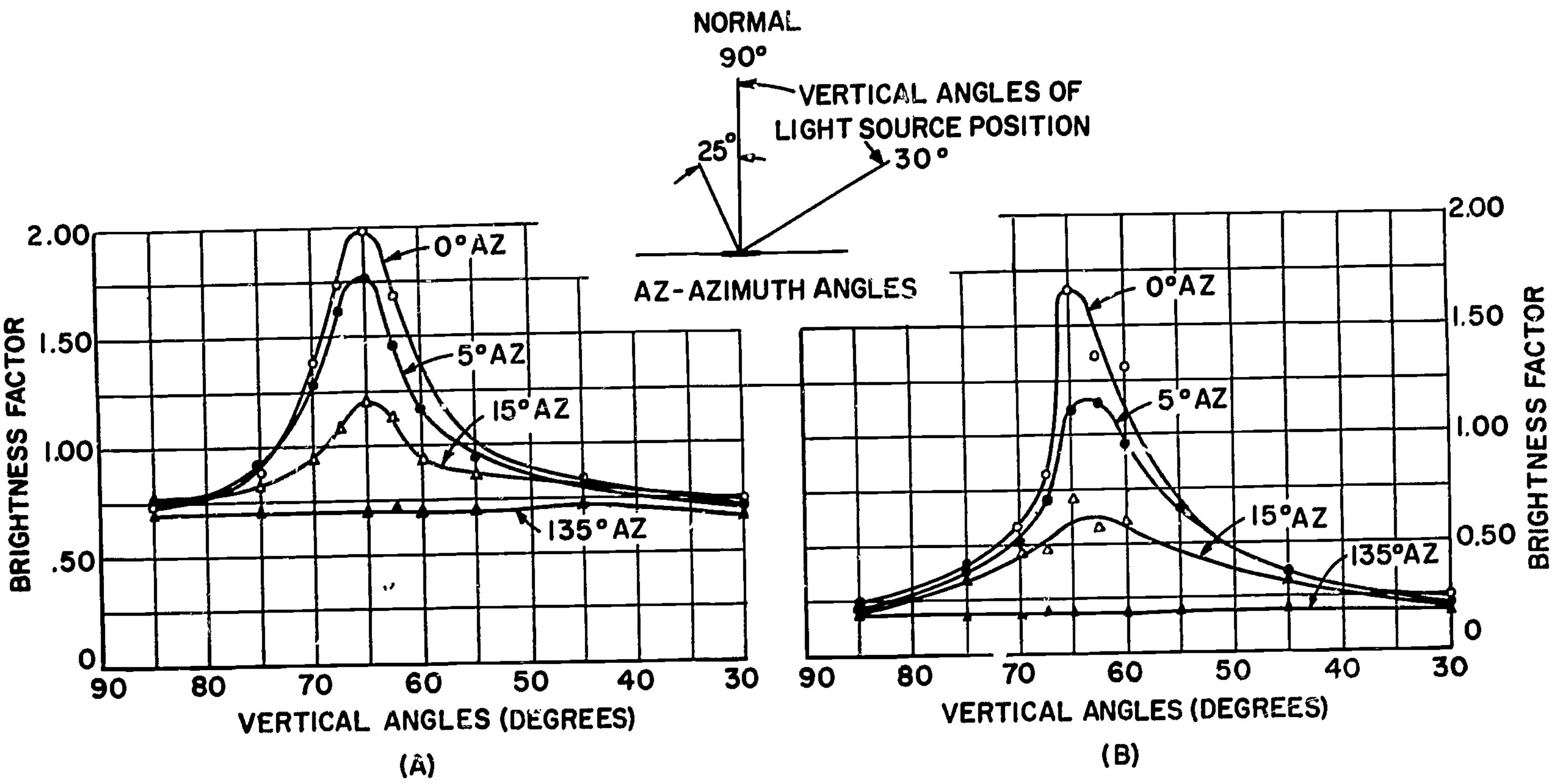


Figure B-1. The effect of light source position upon brightness factor of the (A) background and (B) ink of printed material. Viewing angle is 25 degrees from vertical. Light source position is varied from 30 to 90 degrees from horizontal. See center top inset.

APPENDIX B—REFLECTED GLARE

Evaluating the Effect of Specular Reflection—The net effect of specular reflections from various areas within a visual task is to alter the contrast of the details which must be seen. In most cases this results in a reduction of contrast, but in some instances the contrast may be enhanced.

Recent work by Finch[1] shows that the specular reflection, and hence the contrast, varies with the position of the light source and orientation of the task. This is illustrated in Figs. B-1 and B-2 for printed matter and pencil writing, respectively. The actual samples are shown in Figs. B-3 and B-4, respectively, when illuminated by light coming from various directions. Measurements of this sort emphasize the importance of the paper surface and the indentation of the writing or printing.

From data such as that of Figs. B-1 and B-2 it is possible to compute the contrast of the task details, taking into account the specular reflections produced by a given luminaire located at a specific position with respect to the task and viewing direction. This is done by finding the illumination produced on the detail and converting to brightness by what Finch has termed the "brightness factor." This is equal to the reflectance of the detail as seen from a given angle when illuminated by a specific light source. This can be carried out for a whole installation by determining the brightness increment for each luminaire (or portion of the luminaire, if it is large). By finding the total brightness of the detail and the total from the immediate background, the contrast of the task can be computed for the complete lighting installation. Since these gross values include specular components (as represented by the "humps" in curves of Figs. B-1 and B-2), the optimum contrast may be calculated by eliminating the components in the specular glare zone shown in Fig. 3. By comparing actual installation contrast with the optimum, loss of contrast due to the specular reflections is then able to be determined.

The loss of contrast in any installation may be determined by actual measurement through the use of a contrast threshold meter. Such meters have been developed by Jones[2] and Bennett.[3] Recent versions have been brought out by Cottrell[4] and Finch.[1] Each makes use of the principle of reducing the contrast of the detail *vs* its background to threshold. If specular reflection has already reduced the contrast, the required action of the meter will be less than when the contrast is free of specular reflection. Comparing the meter readings for a given installation when the reflections are occurring and then are shielded out, the reduction due to specular reflection can be determined. This method has some advantages and disadvantages. It has the disadvantage of requiring skilled observers to determine contrast thresholds with a degree of

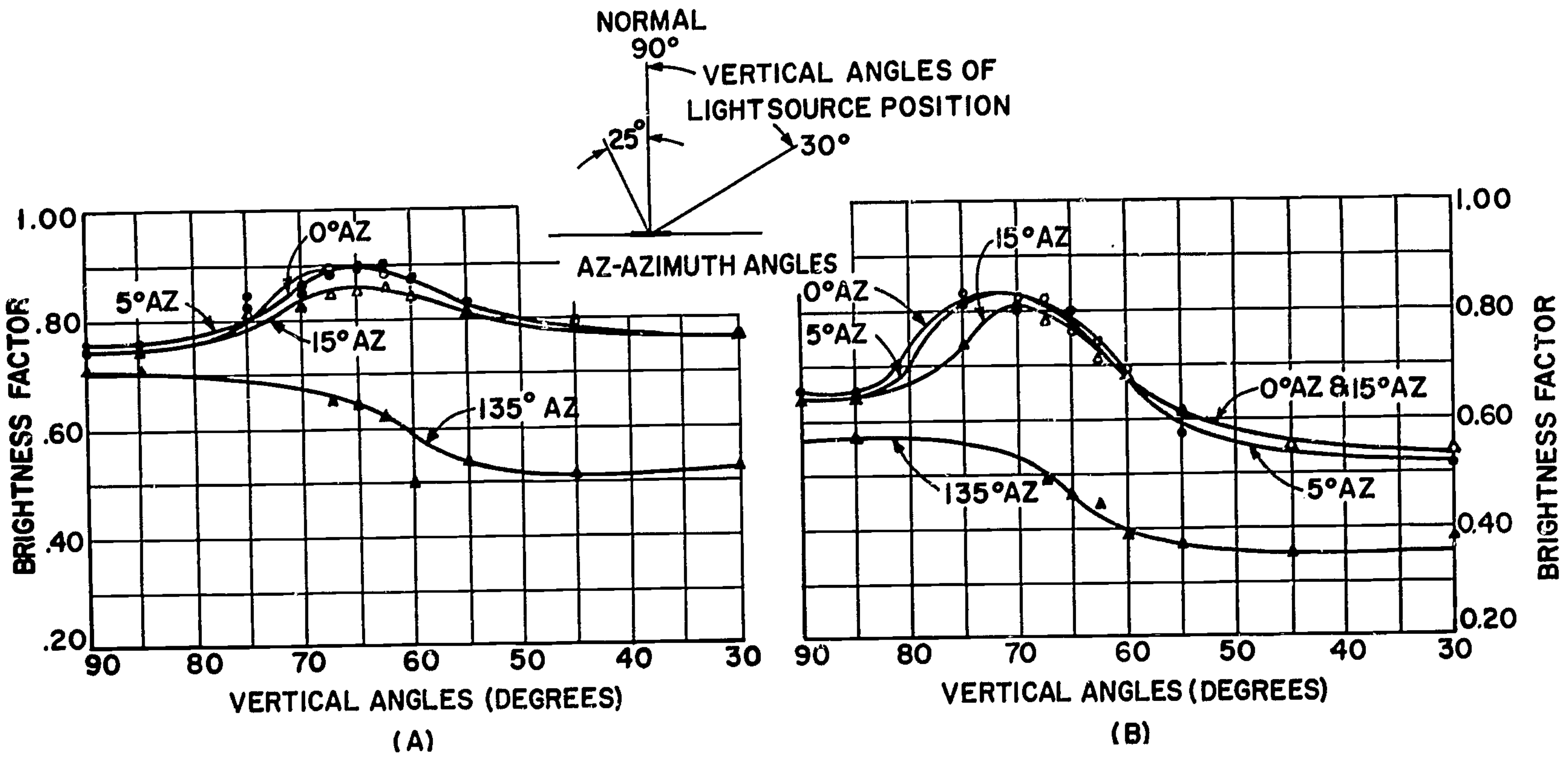
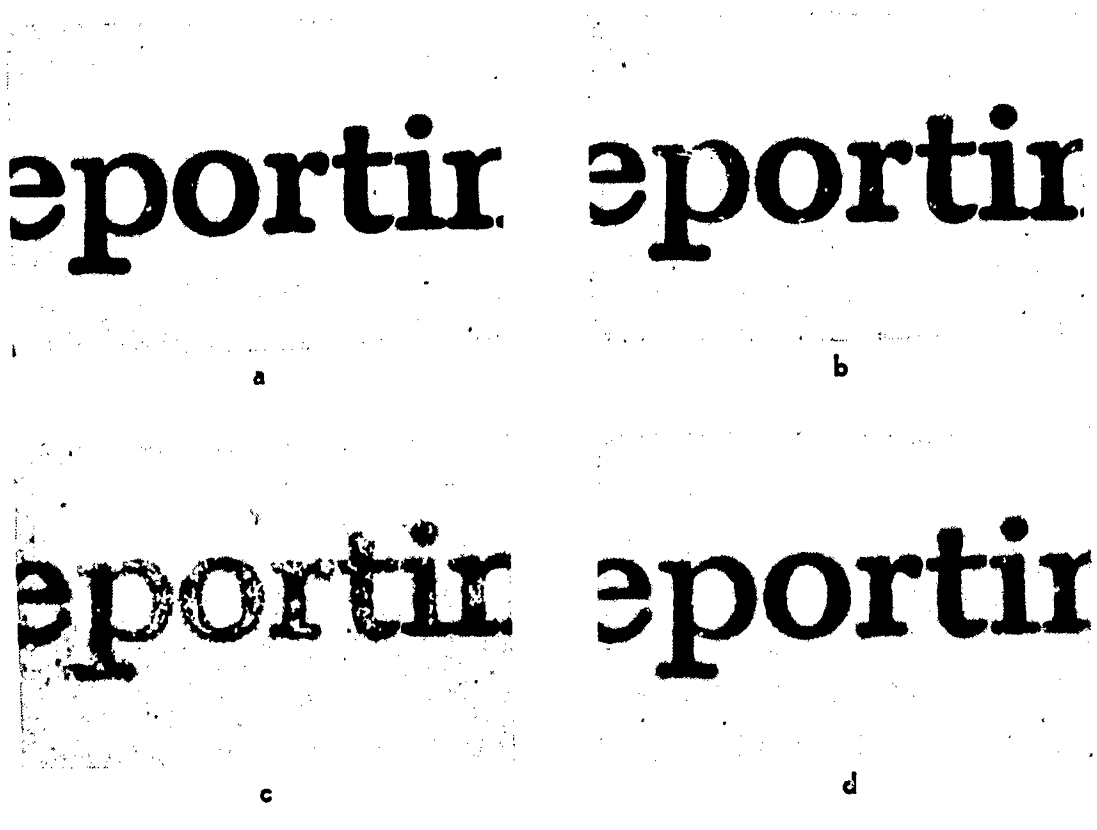


Figure B-2. The effect of light source position upon brightness factor of the background (A) and pencil lines (B) of written material. Viewing angle is 25 degrees from vertical. Light source position is varied from 30 to 90 degrees from horizontal. See center top inset.

photometric consistency, but it has the advantage of seeing what the eye sees with its integration of all the nonuniform details which are generally oriented in many directions with varying indentations and width of line. The above micro-photometric measurements of Finch do not average or integrate the total variation of detail that the eye sees unless a great many samplings of varying detail are taken. Nevertheless, indicative losses of contrast in a given installation can be calculated by the Finch method.

Extensive field measurements have been made by Chorlton and Davidson[5] in a room 23 by 30 by 10 feet under three rows of four-lamp direct-indirect luminaires. Three stations were selected—one 10 feet from the rear wall on a desk under the center row, one 15 feet from the rear wall on a desk under the right hand row, and one 15 feet from the rear wall on a desk half-way between the center and right-hand rows of units. Five tasks were studied—light-weight pencil writing on matte paper, printing on glossy and nonglossy paper, printing on a

Figure B-3. The change in appearance of printed matter due to different directions of incident light. Viewing angle is 25 degrees with vertical. Light source position is at (a) 90 degrees with the horizontal, (b) 40 degrees, (c) 65 degrees and (d) 5 degrees. See center inset in Fig. B-1 for relationship of angles.



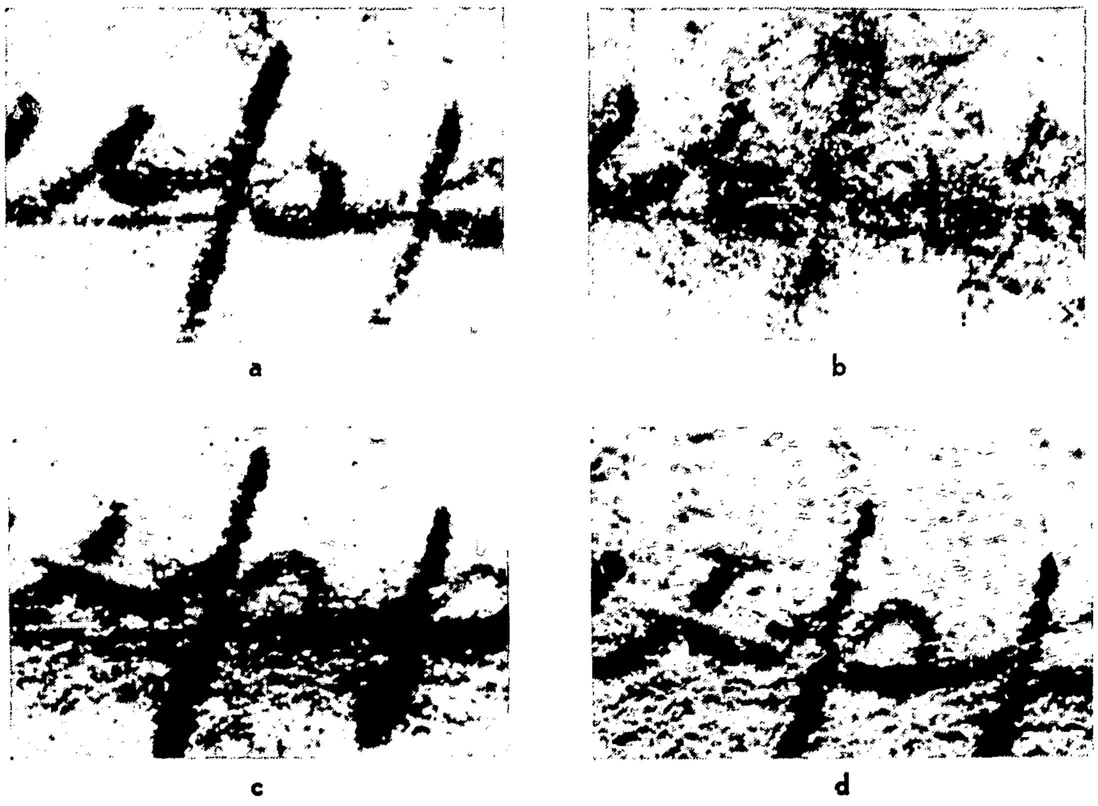


Figure B-4. The change in appearance of pencil writing due to different direction of incident light. Viewing angle is 25 degrees with vertical. Light source position is at (a) 90 degrees with the horizontal, (b) 65 degrees, (c) 40 degrees, and (d) 5 degrees. See center inset in Fig. B-1 for relationship of angles.

matte test card, and heavy pencil work on matte paper. The loss of contrast for light-weight pencil lines on matte paper at each station was measured by a Cottrell contrast threshold meter and found to be 15, 17 and 17 per cent, respectively. Comparatively good printing on semi-glossy stock showed losses of 10, 14 and 15; and the same printing on matte stock gave values of 4, 5 and 11 per cent. Heavy-weight pencil on matte paper showed losses of 19, 21 and 26 per cent.

Significance of loss of contrast due to specular reflections.—Blackwell's data[6] show the relationship between contrast and the brightness necessary to compensate for lower contrasts. Measurements of required quantity of illumination for a specific level of visual performance are determined under no-glare conditions. When glare conditions or specular reflections are encountered, efforts should be made to provide the equivalent no-glare visibility. This can be done by increasing the illumination to compensate for the loss of contrast. For example, with one of their sample tasks, Chorlton and Davidson[5] measured a loss of contrast of 15 per cent on pencil writing with a specific 60-footcandle lighting installation. For this same task, Blackwell found the no-glare illumination requirement to be 63 footcandles. The average reflectance of the task (background and details) was 0.76; thus the brightness was 48 footlamberts. The equivalent contrast of Blackwell's standard target is 0.69. Applying the 15 per cent reduction in contrast to this value indicates a "specular" contrast of 0.59, for which a brightness of about 140 footlamberts (or an illumination of 185 footcandles) gives the equivalent no-glare visibility provided by 63 footcandles. This is illustrated in Fig. B-5.

The Finch method[1] may be used to calculate the relative losses from any lighting system, and Fig.

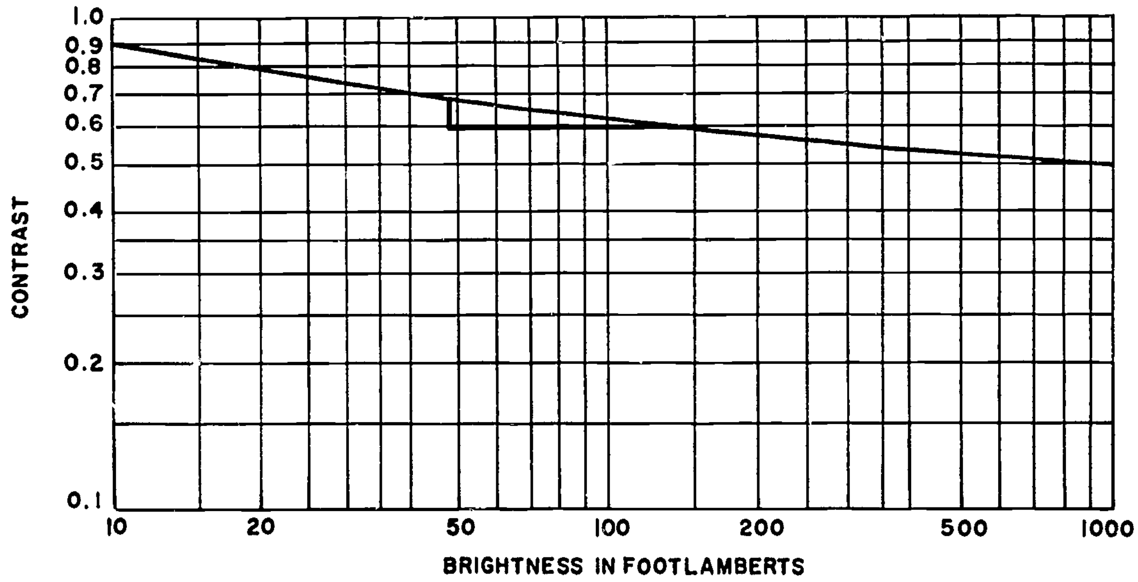


Figure B-5. An illustration of the increase in brightness needed to compensate for a loss in contrast in order to maintain no-glare visibility.

B-5 can be used to determine the increase of illumination necessary to compensate for this loss. As indicated above, the lower the brightness or flux in the specular zone of 0 to 45 degrees (Fig. 3), the greater will be the contrast for a given lighting installation. For general lighting systems this means that the greater diffusion or dispersal of light downward, the greater will be the task contrast resulting from that installation. This also emphasizes the desirability of avoiding tasks which have specular surfaces.

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APPENDIX C—ELECTRIC LIGHTING SYSTEMS

The logical choice of light source and luminaire to be employed depends on the nature of the visual task and the extent of control over features of the environment other than the lighting equipment. Characteristics of applicable light sources and luminaires are important factors in lighting design. These include the first cost of equipment and wiring, energy consumption costs, maintenance and repair, cleaning and lamp replacement cost, physical size, appearance of luminaires when installed in the area, color of light, heating effect, effect of temperature and humidity, lighting and relighting time, noise level, radio interference, etc. Each factor should receive consideration and due weight depending on the application.

Although the C.I.E. classification method* serves as the basis of the selection of luminaires, it should not be confused with a *rating* system. Given control over the reflectances and textures of the entire environment and its contents, visual conditions suited to the most exact seeing tasks can be accomplished with suitably designed equipment of any of the C.I.E. types. Conversely, lacking such control over the details of the luminaires and their environment, unsatisfactory seeing conditions may result regardless of the C.I.E. classification of the luminaire employed. Lighting installations are often classified in accordance with C.I.E. type of luminaire used. The chief characteristics of these types are outlined in the "American Standard Guide for School Lighting."

*Luminaires for general lighting are classified by the International Commission on Illumination (C.I.E.) in accordance with the percentages of total luminaire output emitted above and below horizontal.

Classification	Approximate Distribution of Luminaire Light Output (Per Cent) Upward	Downward
Direct	0-10	90-100
Semi-direct	10-40	60-90
General diffuse	40-60	40-60
Semi-indirect	60-90	10-40
Indirect	90-100	0-10

APPENDIX D—DAYLIGHTING IN CLASSROOMS

The factors to be taken into account and integrated in the daylighting design for schools are as follows:

1. Visual environment recommended for type of work performed.
2. Orientation of fenestration.
3. Fenestration plan.
4. Daylight control medium.
5. Interior decoration.
6. Room and equipment arrangement.
7. Maintenance schedule.

Close visual tasks are performed continually in schools. The basic requirements for school daylighting are an adequate level of well distributed illumination and low brightness ratios within the field of view.

The *orientation* of a building is determined by local conditions. With proper controls, good daylighting can be provided by fenestration for any exposure. Fenestration may be oriented toward the equator to obtain maximum light, or to admit direct sunlight when desired.

It should be noted that, where possible, it is frequently desirable to orient fenestrations to the north and south, rather than east and west. This affords easier design of such fenestrations, either with regard to simple and effective brightness controls on the sun exposure or assuring adequate illumination on non-sun exposures. Obviously, both sun and non-sun conditions occur each day on an east-west exposure and adequate design must account for this fact.

Unilateral daylighting of classrooms is common. For all designs, it is recommended that the light transmitting areas be continuous and preferably extend the full length of the room and up to the ceiling. Whenever the building structure requires piers, they should be kept to a minimum width. Where deep reveals are necessary, they should be splayed. Where building sites and land costs permit, consideration can be given to the use of bilateral lighting in classrooms. For single-story structures, consideration can be given to the use of *clerestory* lighting. The preferred arrangement from the point of view of uniform light distribution and brightness ratios is to face the clerestory in the same direction as the principal fenestration. If the clerestory is faced in the opposite direction, adequate brightness control of the clerestory window is particularly important.

Since the upper part of a window glazed with clear or diffusing media is more effective in lighting the back of the room, the *window head should be as near the ceiling as possible.* The height of the window head above the floor is related to the room width (normal to the window). To achieve the recommended brightness ratios, the *effective width of the room should be limited to the range 2 to 2½ times the distance from the floor to the top of the window for unilateral lighting.*

This depth to height ratio may be effectively extended either by clerestories, as previously noted, or by skylights, where the structure permits. Many types of skylights for such use are available today, including a variety of plastic and glass block systems, in addition to various types of flat glass.

Light-directing panels should start not less than six feet above the floor and should extend to the ceiling. In conjunction with the light-directing panel, a *vision strip* placed in the lower part of the opening should be used to permit a view of the outside. Suitable provision should be made for brightness control of the vision area.

For most circumstances, the amount of daylight from the lower part of a clear glazed window has less effect on the daylight distribution in the room than an equal area higher in the openings. Low sills for outside vision can be used in localities where snow or other ground areas of high reflectance are not a factor.

Of the various types of flat glass, clear glass normally is used for schoolroom windows. Light-diffusing glass may be used but adequate brightness control *must* be provided. Glass block may be used for schools. When used in classrooms with sun exposure, light-directing-type block should be installed above the line of vision. In other rooms, light-directing or other types of block may be used, as long as the light diffusion does not cause uncomfortable brightness in the field of view.

In order to reduce excessive brightness differences, suitable means of daylight control should be provided whenever the sun, bright sky or bright clouds are in the field of view.

Walls, ceilings, floor and furniture should be finished with matte surfaces in light colors of planned reflectance.

A current recommendation of educational authorities is that the brightness distribution within the classroom be such as to allow 360-degree freedom for orientation of desks. Insofar as is compatible with this recommendation, desks should also be arranged so that they use the available light most efficiently.

Definite maintenance schedules should be established for cleaning the glazing and light controlling media. In general, the *fenestration should be cleaned at least twice a year.*